Dell™ PowerVault™ LTO-4-120 Tape Drive
User's Guide

[Preface](#)

[Introduction](#)

[Installing the LTO Driver Software](#)

[Linux Configuration Procedures](#)

[Operation](#)

[Theory](#)

[Specifications](#)

[Troubleshooting Guide](#)

[Getting Help](#)

Introduction

Dell™ PowerVault™ LTO-4-120 Tape Drive User's Guide

This chapter provides an introductory overview of the Dell PowerVault LTO-4-120 Half-Height tape drive.

- Overview
- Features

Overview

The PowerVault LTO-4-120 Half-Height tape drive is a high-performance, 16-channel tape drive that complies with the LTO interchange specifications.

The PowerVault LTO-4-120 Half-Height tape drive uses Ultrium data cartridges. Their capacity is maximized using intelligent data compression. The drive has a capacity of 800 GB (1,600 GB, assuming 2:1 data compression).

The PowerVault LTO-4-120 Half-Height tape drive (see Figure 1-1) has a 5¼-inch half-height form factor with automatic electromechanical cartridge soft load.

Figure 1-1. PowerVault LTO-4-120 Half-Height Tape Drive

Features

Table 1-1 describes the key performance features and capabilities of the PowerVault LTO-4-120 Half-Height tape drive.

Table 1-1. Performance Features and Capabilities

Feature	Description
Cartridge memory	Stores pertinent information about the media to enable fast cartridge loading
Chassis	Shock damped and isolated
Data buffering	128 MB for high performance
Data Encryption	Hardware encryption and decryption supported
Head positioner	Patented proprietary mechanism for increased data integrity
Intelligent data compression	Analyzes compression factors before recording to maximize performance and capacity
Interface	Serial-attached SCSI (SAS)
LSI circuitry	Custom designed for fast and efficient data processing
Native data transfer rate	Up to 120 MB per second
Read channel	Third generation for increased maturity and data integrity
RISC processors	Provide fast and efficient data processing
SmartVerify	Includes two levels of ECC for extra data safety and error protection
Supported operating systems	Microsoft® Windows® 2003 or later, Red Hat® Enterprise Linux 4.0 or later, and SUSE Linux 9 or later
TapeAlert	Monitors and reports drive performance
Tape picking	Enhanced implementation for increased reliability
Variable-speed transfer	Variable speeds for matching with the host to: - Optimize data transfers - Shorten backup times - Increase reliability

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Installing the LTO Driver Software

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This chapter explains how to install the LTO driver software.

If you intend to use the PowerVault LTO-4-120 Half-Height tape drive with the Microsoft® native backup applet on a Windows Server® 2003 operating system, install the appropriate version of the LTO driver software.

The driver software is located on the *Dell PowerVault Documentation and Drivers* CD. However, drivers are often updated, and a more recent version may be available. Please check http://www.dell.com/ for the most up-to-date drivers.

To install the LTO drivers from the *Dell PowerVault Documentation and Drivers* CD:

1. Ensure that you are logged on to the host server with administrator privileges.
2. Insert the *Dell PowerVault Documentation and Drivers* CD into the CD drive on the host computer.
3. Open the device manager (refer to your specific OS documentation for instructions). For example, right-click the **My Computer** icon on the Windows desktop, click **Properties**, and then click **Device Manager**. You can also go to the **Control Panel** and access **System**. Click **Hardware** and then **Device Manager**.

   The LTO-4-120 drive should be listed under the **? Other Devices** item as **QUANTUM ULTRIUM 4 Sequential Device**.

4. Right-click the **QUANTUM ULTRIUM 4 Sequential Device** listing and click **Properties**.
5. Select the **Driver** tab.
6. Click **Update Driver**.
7. When the Upgrade Device Driver Wizard appears, click **Next**.
8. Click **Display a list...** and then click **Next**.
9. Scroll down and click **Tape Drive**, and then click **Next**.
10. Click **Have Disk**, type D:\i386 or D:\amd64, replacing D: with the drive letter for the CD drive into which you inserted the *Dell PowerVault Documentation and Drivers* CD, and then click **OK**.
11. Click the **Quantum LTO 4 Tape Drive** entry, and then click **Next**.
12. Click **Next** to install the driver.
13. Click **Finish**.
14. Click the **Device Properties** dialog box.

    The drive now appears in **Device Manager** under **Tape Drives** as a **Quantum LTO 4 Tape Drive** and is ready to use.

Linux Configuration Procedures
Dell™ PowerVault™ LTO-4-120 Tape Drive User's Guide

This chapter describes how to configure various Linux systems to recognize and obtain optimal performance from the Dell PowerVault LTO-4-120 Half-Height tape drive.

Configuring Linux Environments

This subsection provides procedures for configuring Linux operating system environments.

Finding Existing SAS Controllers and Devices

Use the following command to list the current SAS controllers:

    dmesg | grep SAS

This command produces output similar to:

    SCSI0:LSI Logic SAS based MegaRAID driver

Use the following command to find existing SCSI devices:

    cat /proc/scsi/scsi

This command produces output similar to:

    Host: scsi0 Channel: 0 Id:6 Lun:00
    Vendor: Dell Model: ULTRIUM 4 Rev: 1897
    Type: Sequential-Access ANSI SCSI revision 04

Use the output of these two commands to determine which SCSI target ID numbers are available. In this example, a tape drive is attached at target ID 6.

The widely available distributions of Linux automatically install the proper SCSI and tape device drivers. If you executed the **cat** command to find existing SCSI devices, you have ensured that the SCSI driver for your controller is installed.

Use the following command to view currently loaded modules:

    execute

Verify that one of the entries is st.

Use the following command to view the st device number for your attached tape drive:

    dmesg | grep tape

This command produces output similar to:

    Detected SCSI tape st0 and scsi0 . . .

Configuring the Linux Environment

Procedure

1. Use the **mt** command option to configure the Linux environment.
2. Use the **stsetoptions** command from within the **mt** command to set up a default configuration.

   See the man page for **mt** for details.

   > **NOTICE:** Do not use the erase command. Do not use commands that partition the tape. Partitioning is not supported in the LTO format.

   > **NOTE:** For commands that use density and tape size settings, the tape density is 343,408 bpi and the tape length is 2690 feet. For commands that use a blocking factor, use a factor of 128.

Operation

Dell™ PowerVault™ LTO-4-120 Tape Drive User's Guide

This chapter describes how to operate the Dell PowerVault LTO-4-120 Half-Height tape drive.

- Understanding the LTO-4-120 Front Panel Display
- Using LTO Tape Cartridges
- Cleaning the Tape Drive
- Performing an Emergency Cartridge Eject

Understanding the LTO-4-120 Front Panel Display

As shown in Figure 4-1, the Dell PowerVault LTO-4-120 Half-Height tape drive front panel display has three LED indicators that reflect the operating condition of the drive:

- A seven-segment LED display that provides a single-character code for status, diagnostics, and maintenance functions
- An LED dot display that augments the seven-segment LED
- A two-color (amber/green) status LED

Figure 4-1. LTO-4-120 Front Panel Display
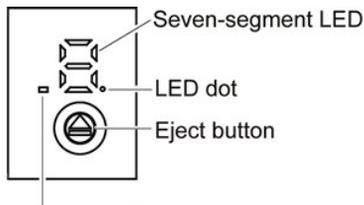
The on/steady, on/flashing, or off condition of the front panel LEDs indicates the various drive conditions as shown in Table 4-1.

Table 4-1. LTO-4-120 Front Panel Display Indications

Drive Condition	Two-color Status LED	Seven-segment LED	LED Dot
Powered off	Off	Blank	Off
Powered on	Off	Blank	Off
Initializing/power-on self-tests underway	Amber	Post pattern, 5	Flashing
Successful initialization/power-on self-tests	Green	Blank	On for 3 seconds
Active/busy or loading or unloading a cartridge	Flashing green	Blank	Off
Ready with cartridge loaded	Green	Blank	Off
Write-protected cartridge loaded	Flashing amber	P	Off
Downloading or updating firmware	Flashing amber	F	Flashing
Running diagnostics	Amber	Displays several characters, such as C, 5, and so on	Flashing
Cleaning required	Flashing amber	C	On
Cleaning operation in progress	Flashing green	C	Flashing
Expired cleaning cartridge	Flashing amber	7	Off
Temperature fault	Flashing amber	1	Off
Power fault	Flashing amber	2	Off
Firmware fault	Flashing amber	3	Off
Firmware/hardware fault	Flashing amber	4	Off
Hardware fault	Flashing amber	5	Off
Media or hardware fault	Flashing amber	6	Off
Media fault	Flashing amber	7	Off
Interface fault	Flashing amber	8	Off
Degraded operation	Flashing amber	A	Off

Using LTO Tape Cartridges

Loading a Tape Cartridge

To load an Ultrium tape cartridge into the Dell PowerVault LTO-4-120 Half-Height tape drive, perform the following steps:

1. Insert the cartridge into the slot.

2. Push the cartridge further into the drive until the drive senses the cartridge and automatically completes the load operation.

Alternatively, use a library or host command to complete the host operation.

Unloading a Tape Cartridge

To unload an Ultrium tape cartridge from the Dell PowerVault LTO-4-120 Half-Height tape drive, either:

- Use a library or host command to unload the tape.
- Press the Eject button on the front panel of the drive.

⚠️ **CAUTION: After you press the Eject button, several minutes can elapse before the drive ejects the cartridge. Do not power down the tape drive or the host computer until the drive has completely ejected the cartridge.**

Write Protecting a Tape Cartridge

Ultrium tape cartridges have a sliding write-protect switch at the right-rear corner as shown in <u>Figure 4-2</u>.

Sliding the write-protect switch toward the . . .	Enables data to be . . .
center of the cartridge (the Locked position),	read from the cartridge, but not written to it. (This is the write-protected position.)
corner of the cartridge (the Unlocked position),	both read from and written to the cartridge. (This is the write-enabled position.)

Figure 4-2. Ultrium Tape Cartridge Write-Protect Switch
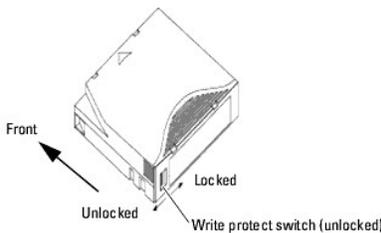
Tape Cartridge Care and Maintenance

Observe the following precautions to protect the data on your Ultrium tape cartridges:

Always:	- Remove the cartridge from the drive when not in use and store it in its protective case. - Avoid dropping the cartridge. This can damage components inside the cartridge, possibly rendering the tape unusable. If you drop a tape cartridge, open the cartridge door and make sure that the leader pin is in the correct position. - Re-tension a dropped cartridge before using. - Keep the cartridge away from: - Direct sunlight and heat sources, such as radiators, heaters, or warm air ducts. - Sources of electromagnetic fields, such as telephones, computer monitors, dictation equipment, mechanical or printing calculators, motors, magnetic tools, and bulk erasers.
Do not:	- Expose the cartridge to dirt, dust or moisture. - Touch the tape media within the cartridge. - Bulk erase Ultrium tape cartridges. LTO tape cartridges have prewritten servo patterns that cannot be reformatted by the tape drive. A bulk erase operation would make them unusable. - Use tape cartridges outside the specified operating conditions: 10° C to 45° C, 10% to 80% relative humidity. If a tape cartridge has been exposed to conditions outside the specified range, recondition the tape before using in the operating environment by exposing it to the operating environment for a time equal to or greater than the time it was outside the operating environment, up to a maximum of 24 hours. Then re-tension the tape to stabilize the tape pack for better performance.

Cleaning the Tape Drive

Excessive tape debris or other material can accumulate on the tape heads if the drive is:

- l   Used with non-approved media
  - l   Operated in a hot, dusty environment

When this happens, the drive can experience excessive errors while reading or writing, and during operations, the LTO-4-120 displays the letter "C" on the seven-segment display and illuminates the amber status LED and the LED dot.

This means that the drive needs to be cleaned.

The LTO cleaning cartridge has the same dimensions as the tape cartridge and contains an LTO Cartridge Memory (LTO-CM), but is loaded with cleaning media instead of recording media. Always keep the LTO cleaning cartridge in its protective case when not in use.

Procedure

To clean the Dell PowerVault LTO-4-120 Half-Height tape drive:

1. Load an LTO cleaning cartridge into the tape drive.

2. Observe that during the cleaning process, the drive displays the letter "C" on the seven-segment LED and both the LED dot and the green status LED are flashing.

    NOTE: If the Dell PowerVault LTO-4-120 Half-Height tape drive does not recognize the cartridge as an LTO cleaning cartridge, the drive stops the cleaning process and ejects the cartridge.

3. After the cleaning process completes, depending on the drive configuration, either:
    o The drive automatically ejects the LTO cleaning cartridge, or
    o If you must press the Eject button to eject the LTO cleaning cartridge, then the LTO cleaning cartridge has expired. Please mark the LTO cleaning cartridge as expired and discard.

4. Write the date on the cartridge label for future reference.

Each time you use the LTO cleaning cartridge, the cleaning media advances to a new, unused section. After approximately 50 cleanings, all of the media will be used up. The Dell PowerVault LTO-4-120 drive displays the number "7" on the seven-segment LED, turns off the LED dot, flashes the amber status LED, and holds the LTO cleaning cartridge in the drive.

Always discard used-up LTO cleaning cartridges.

NOTE: If the clean indication reappears and remains on continuously within 24 hours after a cleaning cycle, perform the cleaning procedure again. If, after three cleaning cycles in a 72-hour period, the clean indication comes on again, contact your Technical Support organization.

Performing an Emergency Cartridge Eject

If the Dell PowerVault LTO-4-120 Half-Height tape drive stops communicating with the host computer, use this emergency procedure to eject the cartridge (if necessary).

CAUTION: When you perform an emergency cartridge eject, any data in the drive or host buffers will not be written to the tape and the tape record may not be correctly terminated with an end-of-data mark. If the end-of- data mark is not written to the tape, you will not be able to append any data to that tape unless you overwrite the existing data on the tape.

To perform an emergency cartridge eject, hold down the Eject button 10 seconds or more, and release it. The tape drive firmware will then ignore all outstanding commands and eject the cartridge.

IF there is . . .	THEN the tape drive firmware . . .
no tape in the drive,	restarts the drive and begins the Power On Self Test function.
a tape in the drive,	ignores all outstanding commands, ejects the cartridge, restarts the drive, and begins the Power On Self Test function.

Theory

Dell™ PowerVault™ LTO-4-120 Tape Drive User's Guide

This chapter describes operational theories used in the Dell PowerVault LTO-4-120 Half-Height tape drive.

- Track Layout
- Recording Method
- Data Buffer
- Data Integrity
- Data Compression

Track Layout

With the PowerVault LTO-4-120 Half-Height tape drive, there are 896 data tracks on the LTO tape, numbered 0 through 895. Data track 895 is the track closest to the bottom edge of the tape (the reference edge).

The area between adjacent servo bands is a data band. There are 4 data bands, each of which includes 224 data tracks. The data bands are numbered 2, 0, 1, 3. Data band 2 is closest to the bottom edge of the tape.

A track group is a set of tracks that is recorded concurrently. The sets of 14 data tracks in a data band are data sub-bands. There are 16 data sub-bands per data band. The data tracks are accessed in a serpentine manner.

A wrap is a track group recorded in the physical forward or physical reverse direction. The wraps are recorded in a serpentine fashion starting in data band 0. The LTO-4 tape contains 56 track groups, 28 written in the forward direction and 28 written in the reverse direction. For each, even-numbered wraps are recorded in the forward direction (BOT to EOT), and odd-numbered wraps are recorded in the reverse direction (EOT to BOT).

Figure 5-1 shows the layout of data on an LTO tape.

Figure 5-1. Layout of the Tracks on LTO Ultrium Tapes

Recording Method

The PowerVault LTO-4-120 Half-Height tape drive records data using write-equalized (0,13/11) Run Length Limited (RLL) code. RLL (0,13/11) Data bits are defined as follows:

- **ONE** is represented by a flux transition at the center of a bit-cell.
- **ZERO** is represented by no flux transition in the bit-cell.

Data Buffer

In its default configuration, the PowerVault LTO-4-120 Half-Height tape drive has a 128-MB buffer. The buffer controller has a burst transfer rate of 320 MB/sec, and utilizes bank switching to achieve a maximum average bandwidth of nearly 240 MB/sec. The high bandwidth is needed to support look-aside data compression in the case of compressible data being transferred from SCSI at 160 MB/sec.

NOTE: Data buffer size and speed do not directly correlate to drive throughput or speed.

Data Integrity

The mechanical and electrical design of the drive ensures that drive performance does not degrade over time. Changes in head alignment, head wear, component drift, and other factors are minimized to ensure that data integrity and interchange capability are not compromised. The drive also incorporates

adaptive Finite Impulse Response (FIR) filters that modify the equalization of each read channel dynamically to compensate for many of those changes.

The error rate of the PowerVault LTO-4-120 Half-Height tape drive is less than 1 hard error in 10^{17} bits. The undetectable error rate is 1 in 10^{27} bits read.

Error-correction Code (ECC)

The use of Cyclic Redundancy Checking (CRC) and two-level orthogonal Error Correction Coding (ECC) provides a very low probability of encountering a hard error. During the read process, ECC correction is performed on the fly without affecting tape streaming.

There are two levels of Error Correction Coding (ECC). These two levels are orthogonal - that is, an ECC codeword at one level intersects ECC codewords at the other level just once, which means there will be only one common symbol between them. The two levels are called C1 and C2.

C1 ECC

As data is written to memory from the data processing unit, the DMA/ECC interface generates C1 ECC bytes and writes them to memory.

As data is written to tape, the C1 ECC is checked and an interrupt generated if there is an error. The C1 ECC read from memory is the ECC that is written to tape.

When data is read from tape and stored into memory, C1 ECC is checked and:

- If the C1 ECC is good, the *valid* bit for the codeword pair is set.
- Otherwise, a pointer to the invalid codeword pair is passed to the C1 ECC correction engine.
  - If the C1 ECC correction engine can correct the error, then the corrected bytes are written to memory, and the *valid* bit is set.
  - Otherwise, the *valid* bit is left cleared.

As data is read from memory to the data processor for decompression, the C1 ECC is again checked and an interrupt generated if it is not correct.

C2 ECC

C2 ECC involves three distinct operations:

1. **Encoding**: Generating C2 ECC bytes from data bytes (performed by ECC coprocessor hardware).

2. **Decoding**: Generating ECC syndromes from data and ECC bytes, testing for all-zeroes (performed by ECC coprocessor hardware).

3. **Correction**: Generating corrected data from syndromes.

The correction depends on the number and types of errors involved:

- For one known C1 codeword pair in error in a subdata set (C2 codeword), the operation is performed by the ECC coprocessor hardware.
- For two or more known C1 codeword pairs in error, the matrix is computed by firmware and the correction is performed by hardware.
- For one or more unknown C1 codeword pairs, syndromes are generated by hardware, error location is computed by firmware, the matrix is computed by firmware and the correction is performed by hardware.

Servo-tracking Faults

During a write operation, if the servo system detects an error that may result in adjacent data tracks being overwritten, the write operation is aborted. The write operation will not continue until the correct servo tracking is re-established.

Data Compression

Typical data streams of text, graphics, software code, or other forms of data contain repeated information either at the text level where you can readily recognize regular repetitions of a single word, or at the binary level where the repetitions are in bits or bytes. Although most data is unique and random, the binary level data exhibits patterns of various sizes that repeat with varying degrees of regularity.

Data compression technology reduces or eliminates data redundancy before recording the information to tape. This increases the amount of data that can be stored on a finite medium and increases the overall storage efficiency of the system.

With data compression, the redundant information in a data stream is identified and represented by codewords or symbols that allow the same data to be recorded in a fewer number of bits. These codewords or symbols point back to the original data string, using fewer characters to represent the strings. Because these smaller symbols are substituted for the longer strings of data, more data can be stored in the same physical space.

Some important benefits result from data compression in tape drives:

- More data can be stored on a given length of tape.
- Performance can more closely parallel to that of high-transfer-rate computers.
- More information can be transferred in the same time interval.

Data Compression Considerations

In an effective data-compression method, several factors are important:

- The amount of compression, which is measured by the compression ratio. This ratio compares the amount of uncompressed data to the amount of compressed data. It is obtained by dividing the size of the uncompressed data by the size of the compressed data.
- The speed with which data is compressed and decompressed relative to the host transfer rate.
- The types of data to be compressed.
- The data integrity of the compressed data.

The amount of compression possible in a data stream depends on factors such as:

- Data pattern
- Compression algorithm
- Pattern repetition length
- Pattern repetition frequency
- Object size (block of information to be compressed)
- Starting pattern chosen

The transfer rate depends on factors such as:

- Compression ratio
- Drive buffer size
- Host computer input/output (I/O) speed
- Effective disc speeds of the host computer
- Record lengths that the host computer transmits

Data compression algorithms can be tailored to provide maximum compression for specific types of data. Because varying types of data are encountered in normal day-to-day operating circumstances, however, an effective data compression method for a tape drive must serve various data types. Additionally, the data compression method must adapt to different data types, automatically providing optimum handling for all types of data.

Intelligent Data Compression

The compressed capacity of the tape is maximized through the use of intelligent data compression. The intelligent data compression hardware determines the compressibility of each record. If the size of the record is larger after a compression attempt than the native size, then the record is written in its native form.

The intelligent data compression utilizes two compression schemes:

- Scheme-1 is a LZ1-based compression scheme using a history buffer to achieve data compression.
- Scheme-2 is a pass-through compression scheme designed to pass uncompressible data through with minimal expansion.

There are three specific requirements for compliance with the LTO specification:

- The output data stream must be decompressible following LTO rules to create the input sequence of records and file marks perfectly.
- An LTO compressed data stream may not contain any of the eight reserved control symbols.
- While control symbols allow switching to Scheme 2, this should never be used by operational software because this capability is only for diagnostic and testing purposes.

Do not use software data compression because the built-in intelligent data compression of the PowerVault LTO-4-120 Half-Height tape drive is much more efficient than software data compression.

The PowerVault LTO-4-120 Half-Height tape drive uses a derivative of ALDC-2 lossless data compression that includes additional control codes for intelligent data compression.

Specifications

Dell™ PowerVault™ LTO-4-120 Tape Drive User's Guide

This chapter provides technical specifications for the Dell PowerVault LTO-4-120 Half-Height tape drive.

- System Requirements
- Physical Specifications
- Power Specifications
- Drive Performance Specifications
- Environmental Requirements
- Injected Noise Specifications
- Reliability Specifications
- LTO Cartridge Specifications

System Requirements

You need the following to properly run your LTO-4-120 Half-Height tape drive:

- **Web browser:** Internet Explorer 5.5 or later, or Netscape Navigator 6.0 or later
- **Minimum operating system:** Microsoft® Windows® 2003 or later, Red Hat® Enterprise Linux 4.0 or later, or SUSE Linux 9 or later
- **CD ROM drive**

Physical Specifications

Table 6-1 lists the physical specifications of the PowerVault LTO-4-120 Half-Height tape drive, which is shown in Figure 6-1.

Table 6-1. Physical Specifications

Specification	Without Bezel	With Bezel	Bracket Adapter
Height	1.63 inches (41.5 mm)	1.70 inches (43.1 mm)	2.04 inches (51.8 mm)
Width	5.76 inches (146.1)	5.87 inches (149.10 mm)	5.75 inches (146 mm)
Length	8.58 inches (218.0 mm) (Max. to end of connector)	8.76 inches (222.57 mm) (Max. to end of connector)	7.66 inches (194.5 mm)
Weight	3.5 lbs. (1.60 kg)	3.6 lbs. (1.625) kg)	

Figure 6-1. PowerVault LTO-4-120 Half-Height Tape Drive Dimensions (Drive Only, Shown Without Bracket Adapter)
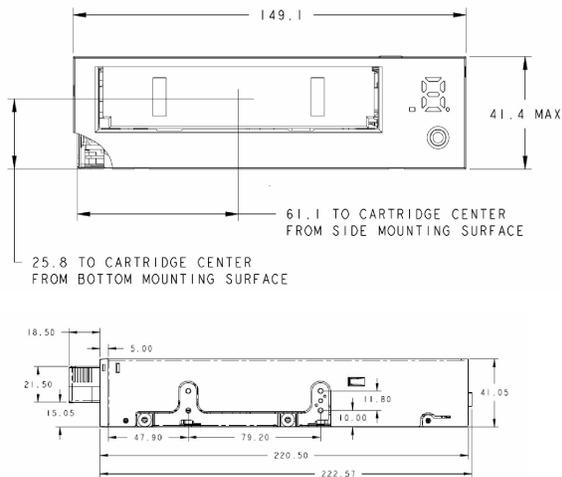
Power Specifications

Maximum voltage and power specifications for the PowerVault LTO-4-120 Half-Height tape drive are listed in and . Specifications are the same as those for other SCSI drives unless otherwise noted.

Table 6-2. Voltage and Current Specifications

Specification	+12 VDC	+5 VDC
DC Voltage Tolerance	12.00 ± 10%	5.00 ± 5%
Non-operating max voltage	14 Volts peak	5.50 Volts peak
Max operating current Continuous: Peak:	 1.70 amps RMS 1.90 amps RMS (1 sec max)	 2.40 amps max RMS* 2.60 amps max RMS*
Standby current (max)	0.37 amps RMS	0.98 amps RMS*
Ripple (peak-to-peak)	< 100 mV	< 100 mV
* RMS parameters measured at the power connector using a true RMS digital meter.		

Table 6-3. Power Dissipation

Power Specification	Dissipation
Max Standby Power	9.3 watts RMS*
Max Continuous Operating Power	31.3 watts RMS*
Max Peak Operating Power	33.2 watts RMS (1 sec max)
* RMS parameters measured at the power connector using a true RMS digital meter.	

Drive Performance Specifications

lists the performance specifications of the PowerVault LTO-4-160 Half-Height tape drive.

Table 6-4. Drive Performance Specifications

Specification	Value
Average data access time (820-m tape) from BOW (beginning of wrap)	56 seconds
Average rewind time (820-m tape) from EOT (end of tape)	> 85 seconds
Capacity	800 GB (native)
Cartridge unload time	25 seconds
Error recovery	Read-after-write Reed Solomon ECC (2 levels)
Flux density (cells per mm)	13250
Head configuration	2 bumps 16 thin-film write heads per bump 16 MR read heads per bump 2 MR servo heads per bump
Maximum data access time from BOW (820-m tape)	112 seconds
Maximum tape rewind speed (meters per second)	8.3
Recording density (RRL-encoded ONEs per mm)	6,760
Recording format (Ultrium 16-channel)	U-416
Recording method	0, 13/11 RLL
Recording undetectable errors	Less than 1 in 10^{27} data bits
Recording unrecoverable errors	Less than 1 in 10^{17} data bits
Synchronous transfer rate (burst)	160 MB/sec max
Tape drive type	LTO (Ultrium)
Tape speed (meters per second)	Up to 6.07
Track density	70 tracks per mm
Transfer rate (sustained), MB/second	120 (max, native)

Environmental Requirements

Table 6-5 lists the environmental specifications of the PowerVault LTO-4-120 Half-Height tape drive.

Table 6-5. Environmental Requirements

Specification	Operational	Nonoperational
Airflow requirements	Internal: 6 CFM (front to back)	N/A
Altitude	-50 feet to 10,000 feet	-50 feet to 35,000 feet
Humidity gradient	10% per hour	10% per hour
Relative humidity	20% to 80% non-condensing	5% to 95% non-condensing
Shock (1/2 sine wave)	31G +/- 5%, 2.6 ms	71G +/- 5%, 2.0 ms
Temperature	+50° to +140° F (+10° to + 60° C)	-40° to +149° F (-40° to + 65° C)
Thermal gradient	10° C per hour over temp. range	20° C per hour over temp. range
Vibration (sweep test)	0.005 inches DA (5-43 Hz) 0.50 G peak (43-1000 Hz) sweep rate 5-1000Hz; 1.0 octave per minute	0.1 inches (5--15Hz) 1.0 G (15-500 Hz) 1.0 octave per minute

Injected Noise Specifications

The LTO-4-120 Half-Height tape drive operates without degradation of error rates with 100 mV of noise injected between the chassis and 0 V at the power connector at any frequency between 45 Hz and 20 MHz.

Reliability Specifications

The PowerVault LTO-4-120 Half-Height tape drive is designed for maximum reliability and data integrity. Table 6-6 lists the reliability specifications.

Table 6-6. Reliability Specifications

Specification	Description
Cartridge load/eject	100,000 cartridge load/eject cycles (no thread)
Error recovery and control	⌐ Error correction code techniques (C1 and C2 ECC) ⌐ Read-after-write (RAW) ⌐ Error monitoring and reporting (error log) ⌐ Retry on
Mean time between failures (MTBF)at 100% duty cycle with power applied and tape moving continuously	250,000 hours
Mean time to replace (MTTR)	Less than 30 minutes
Nonrecoverable error rate	Less than 1 in 10^{17} bits

Mean Time Between Failures

The mean time between failures (MTBF) is specified at 250,000 hours minimum. This specification includes all power-on and operational time but excludes maintenance periods. Operational time is assumed to be 100% of the power-on time. Operational time is the time the tape is loaded.

NOTE: The MTBF rating does not represent any particular drive, but is derived from a large database of test samples. Actual rates may vary from unit to unit.

Mean Time to Replace

The mean time to replace (MTTR) is the average time required by a qualified service technician to diagnose a defective drive and to install a replacement drive. The MTTR for LTO products is less than 0.5 hour (30 minutes).

The LTO drives are field-replaceable units. If a problem occurs with a subassembly or component in the drive, you should replace the entire unit. Return the drive to the factory in its original packaging. Contact your distributor, dealer, or computer system company, or the relevant representative to arrange the return.

LTO Cartridge Specifications

Environmental Considerations

lists the basic environmental tolerances for LTO Ultrium cartridges.

Table 6-7. Environmental Tolerances

Specification	Value
Maximum localized temperature-permanent tape damage	Greater than 52° C
Operating temperature	10° C to 45° C
Relative humidity (non-condensing)	20% to 80% storage, 10% to 80% operating
Wet bulb temperature	26° C max

If during storage and/or transportation a cartridge has been exposed to conditions outside the specified values, it must be conditioned before use in the operating environment. The conditioning shall be exposure to the operating environment for a time equal to, or greater than, the time away from the operating environment, up to a maximum of 24 hours. There shall be no deposit of moisture anywhere on or in the cartridge.

The stray magnetic field at any point on the tape shall not exceed 4000 A/m.

Cartridge Memory

Each Ultrium 1, Ultrium 2, and Ultrium 3 cartridge has 4 KB of nonvolatile memory:

- l 3 KB are used to store tape-directory and hardware specific information.
- l 1 KB is available for application and OEM use.

Each Ultrium 4 cartridge has 8 KB of nonvolatile memory:

- l 4 KB are used to store tape-directory and hardware specific information.
- l 128 bytes are used for error information.
- l 4320 bytes are not used.

The cartridge memory is powered, read, and written to through a radio-frequency link.

Cartridge Reliability

After 5,000 load/eject cycles, replace the cartridge to insure data integrity.

Troubleshooting Guide
Dell™ PowerVault™ LTO-4-120 Tape Drive User's Guide

This chapter provides best-practice installation guidelines for getting the most out of your Dell PowerVault LTO-4-120 Half-Height tape drive, and troubleshooting information you can use to identify and resolve tape drive problems.

- Installation Best Practices
- Troubleshooting Suggestions

Installation Best Practices

Using a Serial-attached SCSI (SAS) Host Bus Adapter

To achieve the best performance from your serial-attached SCSI (SAS) PowerVault LTO-4-120 Half-Height tape drive and optimize your backup operations, attach the drive to a SAS Dell controller that supports 3 GBytes per sec. per port transfer rate.

HBA Preinstallation Checks

Before installing the HBA, check and record your current system configuration. For example:

In the . . . operating system,	You can find information on any currently installed SAS HBA by . . .
Windows	1. Double-clicking **Administrative Tools** in the **Control Panel** 2. Clicking **Computer Management** > **Device Manager** 3. Clicking the SCSI host adapters listed 4. Clicking **Properties** to view the **Resources** tab
Linux	Viewing the boot log text file.

See your operating system documentation for specific information on reviewing your system configuration.

After installing the SAS HBA, restart the system. Make sure the operating system recognizes the HBA and that there are no conflicts with other adapters.

Troubleshooting Suggestions

Computer Does Not Start

If the computer started and operated properly before installing a SAS HBA and the PowerVault LTO-4-120 Half-Height tape drive, but does not start now:

1. Remove the SAS HBA.

2. Restart the system.

3. If the system starts normally, there is a problem with the SAS HBA. Make sure the SAS HBA is compatible with the system and does not have burnt components.

4. If the system still does not start, contact Technical Support.

Computer Hardware Does Not Recognize the Tape Drive

If the computer starts normally but does not recognize the tape drive:

1. Restart the system and check whether the SAS controller is recognized at system startup. You should see messages similar to:

   ```
   SCSI Adapter Manufacturer SCSI BOIS xxxxxxx
   CHA: SCSI ID #, SCSI Device Name
   SCSI ID #, SCSI Device Name
   ```

   If the SAS controller is recognized during system startup, proceed to step 2 to determine whether the tape drive is recognized when the SAS controller scans for devices. Otherwise, contact Technical Support.

2. If the SAS controller is recognized during system startup, restart the system to determine whether the tape drive is recognized when the SAS controller

scans for devices. You should see messages similar to:

```
Bus        Target     Lun        Device
0          0          0          Quantum Ultrium 4
```

If the tape drive is recognized during system startup, the problem has been resolved. Otherwise, proceed to step 3 to determine whether the tape drive is receiving power.

3. If the tape drive is not recognized when the SAS controller scans for devices, check the two-color status LED on the LTO-4-120 Half-Height tape drive front panel to make sure the drive is receiving power (see Figure 4-1).

   If the two-color status LED is not green, proceed to step 4 to check the power connections to the tape drive. If the two-color status LED is green, proceed to step 5 to determine whether the drive passed the Power On Self Test functions.

4. If the two-color status LED is not green, check the power connections to the tape drive.
   a. Shut down the system, remove the cover, and re-seat the DC power cable connector on tape drive.
   b. Restart the system and recheck the two-color status LED.

IF the two-color status LED is . . .	THEN . . .
off,	shut down the system, replace the power connector attached to the tape drive with one from a known working device such as a CD-ROM, and restart the system. If the two-color status LED: l Comes on green, then resolve the problem with the DC power cable/connector. l Remains off, then contact Technical Support to resolve the possible problem with the tape drive.
green,	repeat step 2 of this procedure to confirm that re-seating the DC power cable to the tape drive solved the problem and the tape drive is recognized during system startup. If the tape drive is: l Recognized during the SAS controller scan, then the problem is resolved. Reinstall the computer cover. l Still not recognized, then proceed to step 5 to determine whether the drive passed the Power On Self Test functions.

5. If the two-color status LED is green, but the tape drive is not recognized during the SAS controller scan, use the front panel LEDs to determine whether the drive passes the Power on Self Test (POST) functions. (See Figure 4-1 and Table 4-1.)

IF the LEDs show that the tape drive . . . the POST functions, THEN . . .	
fails	contact Technical Support to resolve the possible problem with the tape drive.
passes	proceed to step 6 to check for possible SAS problems.

6. If the tape drive displays indicate that the drive has passed the POST functions, check the SAS connections:

   a. Shut down the system.
   b. If possible, replace the SAS cable.
   c. If checks a and b do not reveal a problem, contact Technical Support to resolve the possible problem with the tape drive.

Computer Software Does Not Recognized the Tape Drive

Depending on your operating system environment, see the following subsections for troubleshooting guidelines if the LTO-4-120 Half-Height tape drive is recognized by the system hardware at startup, but not by the operating system or applications.

Windows Operating System Environments

When a tape drive is installed in a Windows operating system environment, Windows displays a message on the screen if it does not have a driver in place for the tape drive.

IF the tape drive is for use in . . .	THEN you . . .
an ISV application,	can click the **Cancel** button to clear the message. Most ISV backup software applications invoke their own drivers to run the tape drive.
a native Windows operating system backup utility,	must install the proper driver for the tape drive.

Red Hat Linux Operating System Environments

The tape driver for Red Hat Linux, called **st**, is included as part of the Red Hat Linux operating system.

When Red Hat Linux starts, the operating system recognizes the tape drive and automatically configures it as a device in the **/dev** directory. If it is the first tape device in the **/dev** directory, the tape drive is known as:

> /dev/st0 or /dev/nst0.

There are various ways to view the log files to see whether Linux recognizes the tape drive:

l   One method is to open a terminal window and issue the following command from the root directory:

> dmesg | grep SAS

This command produces an output similar to:

> SCSI0:LSI Logic SAS based MegaRAID driver

l   Another method might be to use the command:

> cat /proc/scsi/scsi

This command produces an output similar to:

> Host: scsi0 Channel: 0 Id:6 Lun:00
> Vendor: Quantum Model: ULTRIUM 4 Rev: 2074
> Type: Sequential-Access ANSI SCSI revision 04

l   You can also use a text editor to view the messages in the file /var/log/ and look for tape drive entries.

l   Sometimes a system can have multiple tape device names in the **/dev** directory and will not know which **st** number to use. To view the **st** device number for your attached tape drive, use the command:

> dmesg | grep tape

This command produces an output similar to:

> st 1:0:0:0: Attached SCSI tape st0

Drive Does Not Load the Tape Cartridge

If you cannot load a tape cartridge into the PowerVault LTO-4-120 Half-Height tape drive:

1.   Verify that the two-color status LED is green and the seven-segment LED is off/blank.

IF the two-color status LED is . . .	AND other LEDs are . . .	THEN . . .
off,	off/blank,	refer to the procedures for troubleshooting power problems under Computer Hardware Does Not Recognize the Tape Drive to determine why the green status LED is not on.
green,	on or flashing,	see Table 4-1 to determine whether the other LED activity is normal or abnormal. Then proceed to step 2 of this procedure. If the seven-segment LED displays the number "4" or "5" to indicate a Power On Self Test error, contact Technical Support to resolve the possible problem with the tape drive.
green,	off/blank,	skip to step 3 of this procedure.

2.   If other LEDs are on, reset the tape drive by pressing and holding the eject button on the front panel for more than 5 seconds and releasing it.

3.   Verify that the tape drive passes the Power On Self Test by viewing the front panel activity (see Figure 4-1 and Table 4-1).

If the two-color status LED is flashing amber and the seven-segment LED displays the number "4" or "5" to indicate a Power On Self Test error, contact Technical Support to resolve the possible problem with the tape drive.

4.   If the two-color status LED is green and the other indicators are off/blank and you still cannot load a tape cartridge into the tape drive, examine the tape and the inside of the tape drive.
   o   Verify that:
       n   There are no tape labels interfering with tape insertion.
       n   Tape labels are only on proper tape surfaces, and that labels are flat and not curled.
       n   The tape drive opening is free of debris and tape labels.
       n   The tape pin and tape are fully within the cartridge.
   o   If you are inserting a cleaning cartridge, verify that the cleaning tape:
       n   Is valid. The tape drive ejects unsupported cleaning tapes.
       n   Has not expired. See Table 4-1 for Expired cleaning cartridge detected .

5. Attempt to insert a different tape cartridge.

6. If a tape still cannot be inserted into the tape drive, contact Technical Support to resolve the possible problem with the tape drive.

Drive Does Not Eject the Tape Cartridge

If you cannot eject a tape cartridge from the PowerVault LTO-4-120 Half-Height tape drive:

1. Verify that the two-color status indicator is green and the other indicators are off/blank.

IF the two-color status LED is . . .	AND the other LEDs are . . .	THEN . . .
off,	off,	refer to the procedures for troubleshooting power problems under Computer Hardware Does Not Recognize the Tape Drive to determine why the green status LED is not on.
green,	on or flashing,	see Table 4-1 to determine whether the other LED activity is normal or abnormal. Then proceed to step 2 of this procedure. If the two-color status LED is flashing amber and the seven-segment LED displays the number "4" or "5" to indicate a Power On Self Test error, contact Technical Support to resolve the possible problem with the tape drive.
green,	off,	skip to step 3 of this procedure.

2. If other LEDs are on, reset the tape drive by either pressing and holding the Eject button on the front panel for more than 5 seconds and releasing it.

3. With the the two-color status LED green and the other indicators off, press the eject button on the front panel.

IF . . .	THEN . . .
the two-color status LED is flashing green with no other indicators on,	wait for the tape to eject (normally takes from 2 to 3 minutes). l If the tape ejects, and the two-color status LED stops flashing green, the problem has been resolved. l If the tape does not eject, and there are no other LED indications, contact Technical Support to resolve the possible problem with the tape drive.
you see a message similar to: You cannot eject the cartridge because the tape drive is in use. Wait until the operation is complete before ejecting the cartridge. The backup software may still have the tape drive in prevent mode so that the cartridge cannot be ejected. Use the backup software commands to eject the tape.	use the **mt offline** command to eject the tape. **NOTE:** In Linux environments, the message may not appear, even though the operating system prevents the drive from ejecting the tape. Use the **mt offline** command anyway.
the two-color status LED flashed amber to indicate a hardware error,	the cartridge might be physically jammed inside the drive. Contact Technical Support to resolve the possible problem with the tape drive.

Slow Backup Operations

Many factors can make backups appear to be slow. To achieve the highest possible transfer rate, the PowerVault LTO-4-120 Half-Height tape drive must be attached to a SAS HBA capable of a minimum of 3 GB/sec. Verify that the tape drive is attached to a Dell SAS HBA. You can do this by:

l Watching the system the startup process
l Examining the system startup log files

IF the tape drive is . . . to a SAS controller,	THEN . . .
attached	proceed to step 2 of this procedure to determine whether the tape drive shares the SCSI bus with another active SCSI device.
not attached	attach the tape drive to a SCSI controller to achieve the best possible hardware performance for the best possible transfer rate.

2. If the tape drive is attached to a SAS controller, verify that the tape drive is detected by:
    o Checking:
        n Windows Device Manager
        n Linux logs

- o Monitoring the SAS controller activity during system startup.

3. The method of performing tape backups can be a factor in slow backup operations. Data sent to the tape drive over a network connection and delays in data transfer over a network connection can cause backups to slow down.

   To determine whether the method of performing tape backups is a factor:

   - o Use the xTalk tape diagnostic software to perform a write/read test. The tape diagnostic software is available at support.dell.com.

⚠ **CAUTION: The read/write test will overwrite any data on the tape. Always use a new/blank or "scratch" cartridge for diagnostic read/write tests.**

   The diagnostic write/read test evaluates the connection between the tape drive and the SAS controller and removes the network data transfer and the backup software from the performance evaluation.

4. When the test finishes, determine the megabytes per second data transfer rate to verify that the tape drive is performing at an acceptable rate.

IF you believe that the read/write transfer rate is . . .	THEN . . .
too slow,	use the tape diagnostic software to perform a trace buffer retrieval. Send the diagnostic output file to Technical Support for evaluation of the SAS condition.
acceptable, but backups still seem to be slow,	it might be attributed to the number of files and the average size of the backup files. These factors can have a significant effect on the backup performance. Backups where the average file size is less than 200 Kbytes, for example, are slower than backups where the average file size is greater than 200 Kbytes. Obtain backup log files to determine number of files and average file size.

Failed Operations TapeAlert Messages

The PowerVault LTO-4-120 Half-Height tape drive supports the TapeAlert standard, and issue the appropriate alert messages in response to operational error conditions. You can view TapeAlert messages either directly, on the system screen, or in the log file of your backup application. Note, however, that some operational error conditions can cause more than one TapeAlert message.

The following subsections provide troubleshooting guidelines for dealing with the most common TapeAlert error conditions.

Backup Failure TapeAlert Messages

A number of problems can cause a backup operation to fail.

This TapeAlert message . . .	Signifies . . .
The operation has stopped because an error has occurred while reading or writing data which the drive cannot correct.	that a media error occurred during a read or write operation. Proceed to step 1 of the following procedure.
The tape is from a faulty batch or the tape drive is faulty. or: The tape is damaged or the drive is faulty. Call the tape drive supplier helpline.	that a media error occurred during a read or write operation. These messages frequently appear in addition to the "The operation has stopped because…" message. In this case, proceed to step 1 of the following procedure. Otherwise, repeat the backup operation with a known good tape and proceed to step 1 of the following procedure if the problem persists.

1. Retry the backup operation if you make any changes are made to the SAS cabling or if you unplug and reconnect any SAS cables.

2. If the problem persists, remove the data tape, insert a cleaning cartridge to clean the tape drive (see Cleaning the Tape Drive).

3. After the tape drive ejects the cleaning cartridge, reload the data tape and retry the backup operation.

4. If the problem persists, use the tape diagnostic software to perform a write/read test with 4 GB of data.

⚠ **CAUTION: The write/read test will overwrite any data on the tape. Always use a new/blank or "scratch" cartridge for diagnostic write/read tests.**

IF the diagnostic test . . .	THEN . . .
completes normally,	retry the backup operation using the same new/blank or "scratch" tape that you used for the diagnostic write/read test. If the backup retry: l Succeeds, discard the original data tape. The problem is resolved. l Fails, repeat step 2 and step 3 off this procedure to clean the tape drive a second time and proceed to step 5 .
fails,	repeat step 2 and step 3 of this procedure to clean the tape drive a second time and proceed to step 5.

5. Retry the backup operation. If the backup retry:
   o Succeeds, the problem is resolved.
   o Fails, contact Technical Support to resolve the possible problem with the tape drive.

Write-Protected TapeAlert Messages

Write-protected TapeAlert messages can appear in response to:

l Actual write-protected tape cartridges
l Defective tape cartridges
l Cartridges of a type that appear to be write protected

This TapeAlert message . . .	Signifies . . .
You are trying to write to a write-protected cartridge. Remove the write-protection or use another tape.	that you are trying to write to a tape cartridge that is actually write protected. 1. Eject the tape cartridge from the drive. 2. Set the cartridge write-protect switch to the unlocked (read-enabled) position (see Figure 4-2). 3. Retry the backup operation.
The memory in the tape cartridge has failed, which reduces performance. Do not use the cartridge for further backup operations. and/or: You have loaded a cartridge of a type that is read-only in this drive. The cartridge will appear as write-protected.	you are trying to write to a tape cartridge that is either defective (failed Cartridge Memory chip), or the wrong type. Retry the backup operation using a known good cartridge of the proper type. If the problem persists, contact Technical Support to resolve the possible problem with the tape drive.
Overwrite protection is set to <setting>. Click OK to overwrite the media or insert new media that can be overwritten.	a software-related problem. See the documentation for your backup software for information on the overwrite and append settings.

Hardware Failure TapeAlert Messages

Hardware failure TapeAlert messages are descriptive and straightforward.

This TapeAlert message . . .	Signifies . . .
The tape drive has a hardware fault: 1. Eject the tape. 2. Reset the drive. 3. Restart the operation. Or: The tape drive has a hardware fault: 1. Turn the tape drive off and then on again. 2. Restart the operation. 3. If the problem persists, call Dell Technical Support.	a tape drive hardware failure.

1. Press the eject button on the front panel to eject the tape cartridge.

2. Cycle the tape drive power to the off then on position:
   a. Terminate all running applications.
   b. Shut down the workstation or server system.
   c. Restart the system.

3. Check the tape drive front panel LED indicators to determine the operational condition of the drive (see Table 4-1).

This LED indication . . .	Signifies . . .
Green green status LED on steady and: All others off	the normal operational configuration. The problem is resolved.
Amber status LED flashing	a hardware failure condition. Contact Technical Support to resolve the possible problem with the tape drive.
Amber status LED flashing and: Seven-segment LED displaying a number	a failed Power On Self Test function. Contact Technical Support to resolve the possible problem with the tape drive.

Tape Cleaning TapeAlert Messages

Tape cleaning TapeAlert messages indicate problems when you insert a cleaning cartridge into the PowerVault LTO-4-120 Half-Height tape drive. Like hardware failure TapeAlert messages, tape cleaning TapeAlert messages are descriptive and straightforward.

This TapeAlert message . . .	Signifies . . .
The last cleaning cartridge used in the tape drive has worn out: 1. Discard the worn out cleaning cartridge. 2. Wait for the current operation to finish. 3. Then use a new cleaning cartridge.	that the cleaning cartridge is used up. Discard it. See Cleaning the Tape Drive and use a new or still functional LTO cleaning cartridge to clean the tape drive.
The last cleaning cartridge used in the tape drive was an invalid type: 1. Do not use this cleaning cartridge in this drive. 2. Wait for the current operation to finish. 3. Then use a valid cleaning cartridge.	the tape drive does not recognize the cleaning tape as being of a valid type. See Cleaning the Tape Drive and use a valid LTO-type cleaning cartridge to clean the tape drive.
The tape drive needs cleaning: 1. If the operation has stopped, eject the tape and clean the drive. 2. If the operation has not stopped, wait for it to finish and then clean the drive. 3. Check the tape drive users manual for device specific cleaning instructions.	the tape drive has issued a message to the backup software to instruct you to clean the tape drive. See Cleaning the Tape Drive.

Getting Help

Dell™ PowerVault ™ LTO-4-120 Tape Drive User's Guide

- Contacting Dell

Contacting Dell

For customers in the United States, call 800-WWW-DELL (800-999-3355).

NOTE: If you do not have an active Internet connection, you can find contact information on your purchase invoice, packing slip, bill, or Dell product catalog.

Dell provides several online and telephone-based support and service options. Availability varies by country and product, and some services may not be available in your area. To contact Dell for sales, technical support, or customer service issues:

1. Visit **support.dell.com**.

2. Verify your country or region in the **Choose A Country/Region** drop-down menu at the bottom of the page.

3. Click **Contact Us** on the left side of the page.

4. Select the appropriate service or support link based on your need.

5. Choose the method of contacting Dell that is convenient for you.

Preface

Dell™ PowerVault™ LTO-4-120 Tape Drive User's Guide

- ● [Audience](#)
- ● [Purpose](#)
- ● [Document Organization](#)
- ● [Related Documents](#)

Audience

This guide is written for users of the Dell PowerVault LTO-4-120 Half-Height tape drive.

Purpose

This guide provides information about the PowerVault LTO-4-120 Half-Height tape drive, including:

- l Installing the driver software
- l Basic drive operations
- l Maintenance
- l Specifications
- l Troubleshooting

Document Organization

This guide is organized as follows:

- l [Introduction](#) provides an overview of LTO and Ultrium technologies, and summarizes the drive's key features.
- l [Installing the LTO Driver Software](#) describes how to install the LTO driver software.
- l [Linux Configuration Procedures](#) describes the configuration settings for Linux systems.
- l [Operation](#) describes the operation and maintenance of the drive.
- l [Theory](#) describes the theory of operation behind the drive, including the technology used in various drive components.
- l [Specifications](#) provides drive and cartridge specifications.
- l [Troubleshooting Guide](#) provides troubleshooting procedures you can follow if you encounter a problem with your drive.
- l [Getting Help](#) explains how to contact Dell for technical support.

Related Documents

The following subsection identifies the primary documents that are related to the PowerVault LTO-4-120 Half-Height tape drive.

Standards Conformance

The Small Computer System Interface is described in standards that include several versions and a number of individual documents. The original Small Computer System Interface Standard, X3.131-1986, is referred to as SCSI-1. SCSI-1 was revised, resulting in the Small Computer System Interface - 2 (X3.131-1994), referred to as SCSI-2. The set of SCSI-3 standards are collectively referred to as SCSI-3. The applicable ANSI standards are as follows:

- l INCITS Technical Committee T10 (SCSI Storage Interfaces) Standards:
  - o SCSI Architecture Model - 2 (SAM-2) INCITS 366-2003
  - o SCSI Architecture Model - 3 (SAM-3) INCITS 402-2005
  - o SCSI Architecture Model - 4 (SAM-4) in development
  - o Automation/Drive Interface - Commands (ADC) INCITS 403-2005
  - o Automation/Drive Interface Commands (ADC-2) in development
  - o Automation/Drive Interface - Transport Protocol (ADT) INCITS 406-2005
  - o Automation/Drive Interface - Transport Protocol - 2 (ADT-2) in development
  - o Fibre Channel Protocol for SCSI (FCP) INCITS 269-1996
  - o Fibre Channel Protocol for SCSI, Second Version - 2 (FCP-2) INCITS 350-2003
  - o Fibre Channel Protocol for SCSI, Third Version - 3 (FCP-3) INCITS 416-2006
  - o Fibre Channel Protocol for SCSI, Fourth Version - 4 (FCP-3) in development
  - o SCSI-3 Medium Changer Commands (SMC) INCITS 314-1998
  - o SCSI Media Changer Commands - 2 (SMC-2) INCITS 382-2004
  - o SCSI Media Changer Commands - 3 (SMC-3) in development
  - o SCSI Parallel Interface - 3 (SPI-3) INCITS 336-2000
  - o SCSI Parallel Interface-4 (SPI-4) INCITS 362-2002
  - o SCSI Parallel Interface-5 (SPI-5) INCITS 367-2003
  - o SCSI-3 Primary Commands (SPC) INCITS 301-1997
  - o SCSI Primary Commands - 2 (SPC-2) INCITS 351-2001
  - o SCSI Primary Commands - 3 (SPC-3) INCITS 408-2005
  - o SCSI Primary Commands - 4 (SPC-4) in development
  - o SCSI-3 Stream Commands (SSC) INCITS 335-2000
  - o SCSI Stream Commands - 2 (SSC-2) INCITS 380-2003
  - o SCSI Stream Commands - 3 (SSC-3) in development
  - o Serial Attached SCSI - (SAS) INCITS 376-2003

- o Serial Attached SCSI - 1.1 (SAS-1.1) INCITS 417-2006
- o Serial Attached SCSI - 2 (SAS-2) in development

l INCITS Technical Committee T11 (Device Level Interfaces) Standards
- o Fibre Channel Arbitrated Loop (FC-AL-2) Amendment 1 INCITS 332.1999/AM1-2003Fibre Channel Generic Services-4 (FC-GS-4) INCITS 387-2004
- o Fibre Channel Generic Services-5 (FC-GS-5) in development
- o Fibre Channel Generic Services-6 (FC-GS-6) in development
- o Fibre Channel - Link Services (FC-LS) in development

NOTE: The term "SCSI" is used wherever it is not necessary to distinguish between the versions of SCSI.